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AUSTRALIAN TUBERALES

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Abstract

An account is given of the Australian representatives of the Tuberales. It includes nine genera with a key to their identification. A new genus *Elderia* has been erected to accommodate a fungus found in the desert of central Western Australia. Two genera occur in Victoria—*Hydnotrya* and *Mukagomyces*. The presence of this latter genus in southern Australia markedly extends its geographic range as previously it has been found only in one province in Japan.

Introduction

The first record of the so-called 'truffle fungi' (Tuberales) in Australia was made by Cooke and Massee (1892). The specimens on which this record was based were collected by members of the Elder expedition (1892-1896) from sandy soil in South Australia and were named *Stephensia arenivaga* Cooke and Massee. In the next year Bresadalo (1893) named some Tasmanian fungi, which had been sent to him for examination, *Genea pazschkei*. McAlpine and Rodway (1896), in a paper dealing with Australian fungi, included a description of a Tasmanian member of the Tuberales under the name *Hydnocystis convoluta* McAlp. Rodway (1897) made the next contribution to this flora when he named specimens of a Tasmanian subterranean fungus *Stephensia varia*. Massee (1898) working with Tasmanian material established *Hydnocystis cyclospora* as present in that State when he elevated *Berggrenia aurantiaca* var. *cyclospora* Cooke to specific rank. In the same year Massee (1898) gave the name *Genabea tasmanica* to some material collected by Rodway in Tasmania. Massee's herbarium is now housed at the New York Botanic Gardens. According to Gilkey (1954), the specimen bearing this epithet, shows no asci nor ascospores of the 'host' fungus, but does bear spores of a parasite which were identified by Dr W. W. Diehl of the Bureau of Plant Industry as *Melanospora zobelli* (Corda) Fckl. Similar spores were wrongly ascribed by Massee and Rodway to the 'host' fungus, so the name *Genabea tasmanica*, as Gilkey remarks, must be regarded as a 'nominum confusum'. In 1925, Rodway described *Terfezia tasmanica* from Tasmanian material in his collection.

Then followed a long interval before any further records were made for Australia. Gilkey (1954) established a new genus *Hydnoplicata* with the type species *Hydnoplicata whitei* on material from Pennant Hills, N.S.W. sent to her by Dr N. H. White of Sydney. These specimens were obtained in 1949 from virgin bushland soil under *Eucalyptus* spp. Another specimen was found in the same area by White (1956) but this proved to be *Labrinthomyces steenisii* Boedijin. Up to this time, this monotypic genus was known only from the type collection from Indonesia; however, Cribb has later (1957) recorded three collections of this species from Queensland as well as the occurrence of the genus *Hydnobolites* in the same State. The distribution of this latter genus was thought previously to be Europe, North America and Indonesia. *Hydnobolites herbertianus* Cribb provided the first record for the genus in Australia.

This account includes all the 'truffle fungi' so far recorded for the Australian continent, with no Victorian representatives. However, Gilkey (1954) discusses a single specimen in Dr G. Massee's collection, reputed to be a Victorian fungus. The notation on the sheet is '*Leucangium readeri* Cke. et Mass., type, Victoria (Dimboola) Reader, damp clay soil'. A description of this species was never published. Gilkey examined the specimen and she states that the spores figured on the sheet by the authors do not depict those of the host fungus but represent spores of the parasite *Melanospora zobelli* and, indeed, perithecia were visible. Although the host ascocarp was immature, Gilkey could discern hyaline globose spores in asci arranged in a palisade. This arrangement would exclude the specimen from the genus *Leucangium* (now regarded as *Picoa*) and the record is regarded by Gilkey as another example of 'nominum confusum'.

Present Investigation

Family Tuberaceae

Genus Elderia McLennan

Dr Donald Thomson sent to me some specimens of Tuberales which he had gathered in August 1958 in the western region of the Central Australian desert area. They were found in loose sand at the base of trees and were partly exposed at maturity. They were eagerly sought by the aborigines and much relished by them as food. The ascocarps varied in size, but the majority are large, 5-6 cm. high, 4-5 cm. broad, soft pale cream to white in colour, and they taper somewhat to the basal region. When they develop in close proximity the apposed surfaces appear flat, otherwise the outer surface is folded in a cerebral-like pattern. Running both across and down the ascocarps are fissures, extending deeply into the tissues and the soft fruit bodies can readily be separated into lobes along these lines (Pl. XVIII, fig. 1). When cut the exposed surface shows very sinuous *venae externae* surrounded by sharply defined *venae internae* (Pl. XVIII, fig. 2-3). The *venae externae* eventually open into the wider fissures which end on, or close to, the exterior surface of the fruit body.

Microtome sections show the presence of a distinct narrow cortical layer of pseudo-parenchymatic tissue, the hyphae composing it are larger in diameter towards the outside, smaller and more compact in the inner layers. The *venae externae* are conspicuous, 1-2 mm. wide, the canals in young fruit-bodies are occupied by spongy hyphal tissue often showing a reticulate appearance, this tissue tends to break down in older ascocarps; only remnants of it remaining in the canals. The *venae internae* lining the canals, consist of a densely compacted tissue which stains deeply. The hymenium is composed of a palisade arrangement of asci and paraphyses; the paraphyses extend into the canals and merge with the spongy hyphal contents. As the asci mature, there is a certain disorganization of this inner tissue, so that the hymenium then appears to line the borders of much convoluted cavities (Pl. XVIII, fig. 3). The asci are long, clavate, and eight-spored, the spores are distichously arranged in the ascus, they are globose, ranging in size from 8·5-12μ, the average size being 11μ, hyaline with a thick (1μ) smooth wall, when fully mature the wall under oil immersion appears minutely pitted.

As the asci form a distinct hymenium bordering *venae externae*, and there is no fusion of the paraphyses to form a secondary cortex, these specimens must be placed in the family Tuberaceae (Gilkey 1954) of the Tuberales. Gilkey presented a key to this family for those representatives of it that are found in North America

and as she states, 'because of our imperfect knowledge of this group', she has included in the keys certain genera not known to occur in that geographical area. In an attempt to place our fungus, attention was given to this key. As the ascocarp cavities (the *venae externae*) were filled with hyphae when young, although breaking raggedly at maturity, it seemed that the genus *Stephensia* might accommodate it.

Gilkey, in correspondence with me, agreed that the specimens showed similarities with some of the characters denoting the genus *Stephensia*, more particularly in possessing the indefinite extension of the paraphyses to form at first a hyphal web in the *venae externae* and in the smooth, globose spores. However, this genus was originally based on its macroscopic ascocarp characters, the distinguishing feature being the presence of a basal or, indeed, even a central cavity from which radiate the *venae externae*, or a least an indication of such radiation even when a cavity is scarcely apparent. As there is no evidence of such a feature in the material under discussion, to extend the description to include these fungi would mean destroying the integrity of the genus.

The first record for Australia of any member of the order, had been made under the name *Stephensia arenivaga* by Cooke and Massee. A fragment of the type specimen is located at the National Herbarium of Victoria, Australia. An examination of this showed me that Cooke and Massee's fungus was similar to our material. Gilkey (in correspondence) had access to the type collection in America and she agreed that the two collections were similar. In her key for the identification of the genera of the Tuberaceae, Gilkey separates sharply those forms in which the 'ascocarp cavities are empty' from those in which they 'are filled with hyphae, these sometimes breaking raggedly at maturity'. If this is a good keying character, our fungus, using this key, would run out to the genus *Densoearpa* Gilkey (1954). In the description of this genus, the ascocarp is described as firm (the generic name is evidently derived from this character), and the peridial characters as given are different from those of the Australian specimens. The microscopic features of the gleba from the description appear to resemble those of our form. As Gilkey has examined some of our material, and is of the opinion that it represents a hitherto unknown type, presumably it cannot fit into the genus *Densocarpa* as understood and established by her.

For these reasons it is proposed to establish a new genus to accommodate this fungus and the name *Elderia* has been chosen as it was first collected by a member of the Elder expedition in 1891.

ELDERIA *E. I. McLennan*

Genus novum Stephensiam Tulasne maxime accedit, sed. venis externis ascocarpi irregulariter dispositis (haud a cavo centrali radiantibus)

Aseocarpus pallidus (albus vel isabellinus), pernollis, radieem versus gradatim eontraetus, longitudinaliter et transverse penetratus a fissuris profundis in quas venae externae pateseunt, superfieie cerebriformiter plicata. Peridium a pseudo-parenehymate impletum. Gleba ex venis internis multiplieibus consistens; venae gerentes hymenium, cuius textus dis-ponitur in vallo ascorum et paraphysium; paraphyses in venas externas protrudentes, in his canalibus textum reticulatus formantes (eanales ad maturitatem dissolvuntur). Venae externae irregulariter dispositae. Asci sporis 8. Sporae globosae, leves vel perleniter foveolatae.

Ascocarp pale coloured white to isabelline hypogaeous becoming epigaeous when mature, very soft, tapering towards the basal attaching region, traversed

longitudinally and transversely by deep fissures, into which the *venae externae* open, flattened on the sides by mutual pressure of adjacent ascocarps. The upper surface folded in a cerebral pattern. Peridium pseudo-parenchymatic, the hyphae small and compact in the inner layers. The gleba consists of much folded *venae internae* bearing the hymenial tissue which is arranged in a palisade of asci and paraphyses, the latter projecting into the *venae externae* and forming a reticulate tissue in these canals, which disorganizes in the mature stages of the ascocarp. The *venae externae* open into the deep external fissures. The asci are clavate eight spored, the spores are globose smooth to faintly pitted.

Type species **Elderia arenivaga** (Cooke) McLennan

syn. *Stephensia arenivaga* Cooke

Ascocarps up to 7 cm. high, 3-4 cm. across, deeply lobed, pale, upper surface cerebriform the lower part of the peridium with closely adherent sand particles. Asci clavate, spores eight, irregularly arranged in the ascus, hyaline, globose, average diameter 10μ (range 8·6-12μ).

TYPE: Collected in sandy soil, South Australia.

HABITAT: In sandy desert areas.

DISTRIBUTION: NW. of South Australia (near Everard Range) and central W. of Western Australia (near Lake Hazlett).

Genus **Hydnotrya** Berk. et Br.

Some specimens gathered by the author a few years ago at Narbethong, Victoria, Australia, were placed provisionally as *Hydnocystis convoluta* McAlp. (1896). McAlpine described his specimens as 'entirely white, an irregular convoluted hollow sac about 2 x 2 inches and narrowing towards the ground, wall about one line thick and composed of an outer layer of sub-cartilaginous, or brittle fleshy substance and an inner one of compact hymenium. Asci cylindrical up to 256μ long, intermixed with slender filamentous paraphyses. Spores spherical or oval, slightly verrucose, about 9μ in diameter or 10-11 x 8·5μ. On ground in woods, Hobart, Tasmania.'

This description adequately fits the Victorian specimens.

Massee (1898), discussing some Tasmanian fungi, lists *Hydnocystis cyclospora* (Cooke) Massee with its synonym *Berggrenia aurantiaca* var. *cyclospora* Cooke (1886). He noted that Cooke gave the measurements of the variety *cyclospora* as 18μ. However, examination of the type material by him proved this to be incorrect and showed the spore range to be from 9-12μ. I have examined some of the co-type material of *Hydnocystis cyclospora* from the Rodway herbarium and it has proved to be similar to the fungi found at Narbethong, Victoria, with rough spores, although, Rodway (1924) in his description of this fungus states that the spores are smooth.

Massee placed *H. convoluta* McAlp. into synonymy when he erected the varietal name of *Berggrenia aurantiaca* var. *cyclospora* Cooke to specific rank. According to the rules of nomenclature this is not permissible, so *H. cyclospora* (Cooke) Massee must yield to *H. convoluta* McAlp. Gilkey, however, interprets the genus *Hydnocystis* as possessing smooth spores in contrast to *Hydnotrya* with sculptured spores. As the Australian fungi have verrucose spores they should be placed in the latter genus and the nomenclature becomes—

Hydnotrya convoluta (McAlp.) McLennan

syn. *Berggeneria aurantiaca* Cooke var. *cyclospora* Cooke (1886)
Hydnocystis convoluta McAlp. (1896)
Hydnocystis cyclospora (Cooke) Massee (1898).

As already noted, the original description by McAlpine of *H. convoluta,* based on Tasmanian material fits the characters of the Victorian specimens. The spores were described as spherical or oval, slightly verrucose about 9μ in diameter or 10-11 x 8·5μ. The spore measurements of the co-type material from Rodway's collection are approximately 12 x 8μ and for the Victorian samples 12 x 8·4μ.

The only other Australian record of *Hydnocystis* is Rodway's species *H. echinospora* (1924). Examination of the type material now housed in the herbarium of the Tasmanian University (No. 374) shows that he was mistaken in referring it to the Tuberales. The hymenium clearly covers the outer surface of these small fruiting bodies, which are hemispheric and somewhat convoluted with a hollow interior. Rodway described the spores as uniseptate (probably in error for uniseriate) ; specimens preserved in his herbarium under this name show no signs of spore septation, they are elliptical and, as he states, the spore surface is ornamented with rather coarse blunt spines. It is interesting to note that he originally named and described the specimens as *Sphaerosoma tasmanica,* a genus with the hymenium completely clothing the exterior surface of the ascocarp, although Rodway (1919) describes the hymenium of his specimens as covering the internal surface!

The name *Hydnocystis echinospora* Rod. must be regarded as superfluous.

Family Terfeziaceae

Genus Mukagomyces Imai

During the autumn of 1955, the writer collected a number of specimens of a Tuberales at Footscray (a suburb of Melbourne), Victoria. They were growing in a municipal gardens close to the roots of *Populus canadensis* Moench, and, at that time, the mycelium was traced to the roots of this tree. Later the rootlets were shown to possess a mycorrhizal association, probably the fungal partner was the truffle fungus although no actual proof of this was possible. These fungi were members of the Terfeziaceae, for the ascocarps were very compact and lacked any internal cavities, i.e. *venae externae* were absent. However, the fertile tissue was divided by sterile veins into many nest-like areas containing clavate to spherical asci. The asci were few spored, the spores were ellipsoid and conspicuously alveolate.

Using Gilkey's key in an attempt to identify these fungi, they ran out to the genus *Mukagomyces* Imai (1940), a genus so far known only from Japan. The ascocarps were subterranean, compact, very variable in size, the larger 3·5 cm. broad by 2-2·5 cm. high, opaque and whitish externally. The surface of some is much folded in a cerebriform pattern, while others are smoother and plicate towards the base. The gleba is pinkish-cinnamon traversed by sterile veins of a lighter colour. The outer coat is white, 1 mm. thick, and covers the ascocarp completely, there are no openings to the exterior of the fruit body (Pl. XIX, fig. 2).

In section the periderm shows as a densely parenchymatic structure becoming slightly more prosenchymatous, but still dense towards the glebal region. The gleba is separated into pockets by a less compact sterile tissue. The asci are globular to elliptical and 4-8 spored. The spores are variable in shape oval to elliptical and range in size from 30-40 x 20-28μ. The spore coat is brown and shows an alveolate pattern, the ridges forming the boundaries of the network are deep so that a conspicuous wing surrounds the spore when it is viewed in optical section. In

surface view the alveolae are mostly pentagonal to hexagonal in outline and measure approximately 7μ across (Pl. XIX, fig. 1).

A comparison of Imai's description for the Japanese fungus with the above description of the Australian forms makes it clear that we are dealing with the same genus and species. It is a monotypic genus and Imai has named the type species *Mukagomyces hiromichii*. The occurrence of this species in southern Australia (Victoria) markedly extends its geographic range for until now it has been known only from one province in Japan.

The other member of the Terfeziaceae to be considered for Australia is *Terfezia tasmanica* Rod. (1925). This genus differs from *Mukagomyces* in having an 8-spored ascus. The material in the Rodway herbarium of *T. tasmanica* shows the typical generic characters. Rodway gives the spore characters as 'globose-pyriform, minutely echinulate, coat thick forming a double contour hyaline till old, then brown, 20μ diameter'.

Examination of the type material, as well as some slides prepared by Rodway in my possession, shows the spores to be markedly thick-walled, with many narrow pits, the orifices of which in surface view show as small circular areas over the spore surface (Pl. XIX, fig. 3). The spores are not echinulate as the original description states.

Key to the Australian Tuberales*

*Adapted from the key prepared by Professor Gilkey (1954) for the North American Tuberales

KEY TO THE FAMILIES

(A) Asci forming a distinct hymenium

(a) Hymenium in the form of a paliside the paraphyses fused beyond the tips of the asci to form an epithecium .. .. GENEACEAE

(b) Hymenium irregularly arranged, or if in palisade the paraphyses not fused to form an epithecium .. .. TUBERACEAE

(B) Asci not forming a distinct hymenium, but borne in nest-like areas separated by sterile tissue .. .. TERFEZIACEAE

KEY TO THE GENERA

Family GENEACEAE

(A) Mycelial tuft present

(a) Ascocarp opening single, spores sculptured .. .. *Genea*
G. pazschekei (Tas.)

(B) Mycelial tuft absent

(a) Ascocarp openings one to several, spores smooth .. .. *Hydnoplicata*
H. whitei (N.S.W.)

Family TUBERACEAE

(A) Hymenium with asci and paraphyses in palisade lining the walls of cavities

(a) Ascocarp cavities empty, paraphyses only one-third as long as the asci .. .. *Labrinthomyces*
L. steenisii (N.S.W. and Qld.)

(b) Ascocarp cavities empty, paraphyses as long as the asci .. *Hydnotrya*
H. convoluta (Vict. and Tas.)

(c) Ascocarp cavities containing hyphae which become pulled apart at maturity

(i) Ascocarp with a basal cavity from which radiate the venae externae .. *Stephensia*
S. varia (Tas.)

(ii) Ascocarp lacking this radiate structure. The venae externae form a much convoluted system of canals .. .. .. *Elderia*
E. arenivaga (E. and W. Central W.A.)

(B) Hymenium without palisade structure, the asci irregularly arranged .. *Hydnobolites*
H. herbertianus (Qld.)

Family Terfeziaceae

(A) Asci 8-spored, spores globose .. .. *Terfezia*
T. tasmanica (Tas.)

(B) Asci 4-spored (rarely more) spores ellipsoid .. .. *Mukagamyces*
M. hiramichii (Vict.)

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Explanation of Plates

Plate XVIII

Fig. 1—Aseoearps of *Eldcria arenivaga* nat. size.
Fig. 2—L.S. through an aseoearp of *E. arenivaga.* The *venae externae* are irregularly arranged nat. size.
Fig. 3—A seetion through an aseocarp of *E. arenivaga* x35.
1. *venae internae,* 2. palisade hymenium, 3. paraphyses in *venae externae.*

Plate XIX

Fig. 1—An aseus of *Mukagamyces hiramichii* Imai.
1. alveolate pattern of spore eoat x1200.
Fig. 2—Aseoearps of *Mukagamyces hiramichii* Imai nat. size.
Fig. 3—Aseospores of *Terfezia tasmanica* Rod. x1800.